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# NATURAL DISASTER REDUCTION: HAZARD RESISTANT STRUCTURES

## Technical session

## Programme

The technical session on hazard resistant structures has been organized by the International Council for Scientific Unions (ICSU) Special Committee for the International Decade for Natural Disaster Reduction, representing both ICSU and the global engineering organizations World Federation of Engineering Organizations (WFEO)/Union of International Technical Associations (UITA).

Introduction by Sir James Lighthill, Chairman, Special Committee for the International Decade for Natural Disaster Reduction of ICSU (10 minutes)

The introductory statement will address the general theme, "What science and technology can do for natural disaster reduction", exemplified both by the present session and by the session on warning systems, organized by the World Meterological Organization (WMO). Reference will also be made to hazard assessment programmes in the context of identification of regions of high priority for hazard-resistant construction.

Accounts of the interface between these two Technical Committee Sessions then follow. They are typified by aspects of the ICSU/WMO demonstration project on tropical cyclone disasters, including programmes on both forecasting of, and preparedness against, tropical cyclones in many countries of the world.

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Contribution by Professor J.R. Choudhury (Bangladesh) (20 minutes)

The presentation will describe the development, construction and use of cyclone shelters, namely, structures resistant to the storm-surge inundation that a tropical cyclone may generate (especially in low-lying areas of Bangladesh) and which, provided proper training is given in their use, are able to protect people, along with many of their most valued possessions, after a warning has been received. (Note. Besides their use in an emergency, the shelters are suited also to a wide variety of community uses.)

Contribution by Professor A.G. Davenport (Canada), head of the famous Boundary Layer Wind Tunnel Laboratory, University of Western Ontario (20 minutes)

This presentation will survey design, construction, quality assurance and maintenance problems of structures resistant to extreme-wind loads, such as a tropical cyclone may generate (with emphasis on the Caribbean and Philippines experience) or to earthquake loads. The paper outlines the contributions made towards improvement of hazard resistance that can be made by a structure's user, owner, investor, insurer and builder, as well as by individual material suppliers, design professionals, building officials, code writers and inspectors.

Contribution by the representatives Mr. Stuart Mustow and Mr. Scott Steedman (30 minutes)

This presentation is concerned with techniques of design and construction of relatively low-cost structures that are resistant to extreme-wind disasters or earthquake disasters, as well as with associated quality-assurance issues related to problems of securing enforcement of building codes.

The presentation, with special emphasis on engineered structures, refers to several case-studies; for example, in the earthquake engineering field, these are derived from experience with the Erzincan (Turkey) earthquake of March 1992 and the Cairo (Egypt) earthquake of October 1992. Also, the important concept of "seismic-hazard auditing" will be illustrated by a case-study in Colombia.

Contribution by Professor A.S. Arya (India), member of the Scientific and Technical Committee (20 minutes)

This presentation, on the protection of non-engineered housing from natural hazards, brings together knowledge derived from age-old indigenous approaches and the results of research carried out in the past few decades on the achievement of disaster protection for such buildings. The methods described, of an incremental nature (maintaining, and yet adding to, the basic materials and techniques already used, rather than replacing them completely) are found to be socially acceptable, economically feasible and easily absorbed into local construction methodologies. The presentation ends with recommendations on the transfer of the necessary knowledge to local levels.

Contribution by Professor A.A. Giesecke (Peru), member of the Scientific and Technical Committee (10 minutes)

This presentation is concerned with methods for reconditioning existing adobe housing so as to mitigate the effects of earthquakes. The basic emphasis is on simple, low-cost procedures for such reconditioning that take into account size, shape and construction characteristics and soil types and that are aimed at delaying collapse sufficiently to save many lives by allowing time for escape.

Contribution by a representative of the Malaysian Rubber Producers Research Association (10 minutes)

This presentation will deal with the promise of new techniques being developed in cooperation with the United Nations Industrial Organization (UNIDO), on use of a new and highly effective type of latex base-isolators, initially for engineered structures but capable of development for producing rubber bearings suitable for earthquake protection of low-cost housing.

General discussion (50 minutes)

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# NATURAL DISASTER REDUCTION: HAZARD RESISTANT STRUCTURES

## Technical session

## Addendum

## What science and technology can do for natural disaster reduction

## Summary of introductory statement by Sir James Lighthill, Chairman, Special Committee for the International Decade on Natural Disaster Reduction, International Council of Scientific Unions (ICSU)

1. Science and technology have important parts to play in the International Decade on Natural Disaster Reduction (IDNDR), particularly in improving the timeliness and reliability of forecasts of natural disasters, refining assessments of risk of such disasters, and (above all) enhancing preparedness wherever the risk is substantial. Preparedness includes the promotion of public awareness of risk, and also of the action required in response to disaster forecasts; however, it is by means of hazard resistant structures that the greatest saving of life and of valued property can be achieved.

2. All of the work of the Special Committee of ICSU is devoted to strengthening the contribution of science and technology to disaster forecasting, risk assessment and the enhancement of preparedness, for example, in:

(a) The joint ICSU/World Meteorological Organization (WMO) programme on tropical cyclone disasters - aimed at improving forecasting of, and preparedness against, extreme wind loads and storm-surge flooding caused by tropical cyclones (see technical committee session F on warning systems);

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(b) The Global Seismic Hazard Assessment Programme - aimed at achieving, through a regionally coordinated approach to seismic hazard construction, updated national assessments of earthquake risk in order that high priority areas for earthquake-resistant construction can be identified;

(c) The WFEO/UITA project on design and construction of buildings to withstand natural disasters - aimed at using case-studies to identify key actions needed to ensure practical implementation of the principles of disaster-resistant construction.

Another two projects of the Special Committee of ICSU are dedicated to the promotion of public awareness.

3. Several different types of hazard resistant structure will be described. They include shelters, suitable for use where reliable disaster forecasting is available (e.g., for tropical cyclones in the Bay of Bengal), and also general-purpose structures able to give protection even when (as with most earthquakes) no disaster warning is achievable. Attention is directed at problems of how to attain adequate hazard resistance in new construction (whether of an engineered or non-engineered type) and of how to improve hazard resistance in existing structures so that risks to their inhabitants are greatly mitigated. Special attention is given to considering implications for national policy makers, as well as for all those engaged in the various industries concerned with construction.

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# NATURAL DISASTER REDUCTION: HAZARD RESISTANT STRUCTURES

## Technical session

## Addendum

## Cyclone shelters in areas prone to storm surge

Summary of presentation by Professor Jamilur R. Choudhury, Department of Civil Engineering, Bangladesh University of Engineering and Technology, Bangladesh

1. Storm surges, which accompany tropical cyclones, are among the most damaging of natural disasters in terms of loss of human lives. In Bangladesh alone, about 750,000 people have lost their lives in 20 major cyclones and storm surges during the past 30 years. The regions of the world which are vulnerable to such disasters include the islands in the south-west Pacific, south-east Asia (e.g., the Philippines, Viet Nam), countries adjoining the Bay of Bengal (viz., India, Bangladesh and Myanmar), south-east Africa, the Caribbean, and parts of the United States of America and Latin America around the Gulf of Mexico and Atlantic Ocean. Bangladesh is among the countries most vulnerable to devastating storm surges (with heights up to 7.5 m) which accompany cyclones. Around 5.3 million people live in the high-risk coastal areas and off-shore islands, with an average density of around 600 persons per square kilometre.

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2. The ideal solution for protecting human lives is to build houses above the surge level and make them strong enough to resist the lateral forces due to high wind and the accompanying surge. The investment necessary even for building only one room per family (around US$ 2,500) is too high for the poor people in the area. However, community shelters constructed during the past three decades have provided refuge to a large number of people. These are usually buildings of two or three stories supported on reinforced concrete columns, with the ground floor left open to allow the surge water to pass through the building unimpeded. Experience shows that in order to facilitate easy movement to the shelters, the shelters have to be very closely spaced with a maximum walking distance from house to shelters of around 1.5 kilometre. Also, people are reluctant to go to a shelter where there are no provisions for protecting livestock.

3. Based on the above considerations, design for integrated shelters for the human population as well as livestock (with one-storied buildings built on earthen mounds) have been prepared. Special provisions have been made for water supply, sanitation and lighting for these shelters. Since these are likely to be used as shelters only once in four or five years, it would be difficult to justify the huge investment unless some normal times use of the facilities is ensured. Moreover, experience shows that lack of regular use leads to rapid deterioration of the physical condition of the facilities.

4. A variety of uses for these multi-purpose shelters has been suggested. These include, inter alia, educational institutions (primary schools, secondary schools), community centres and family welfare centres.

5. To ensure full use of the shelters during cyclones and storm surfaces, the following measures are being implemented: improving the reliability of the warning system; training of volunteers for dissemination of warnings and assistance in evacuation to shelters; pursuing a public awareness programme, including regular drills; and ensuring community involvement in shelter management.

6. It is expected that, with the completion of the multi-purpose cyclone shelter project leading to the construction of around 2,500 new shelters, the colossal losses of human lives and livestock during cyclones and storm surges can be prevented. Moreover, the availability of these facilities during normal times for delivering educational and health services, and their use for other community activities, will have a far reaching effect in accelerating the pace of socio-economic development of the vulnerable communities.

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# NATURAL DISASTER REDUCTION: HAZARD RESISTANT STRUCTURES

## Technical session

## Addendum

## Reduction of structural vulnerability to natural disasters

Summary of presentation by Professor A.G. Davenport, Faculty of Engineering Science, University of Western Ontario and Chairman. National Committee for the International Decade on Natural Disaster Reduction of Canada

1. Structural failure, and the dislocation and loss of life that results, is a primary cause of the disasters that follow severe windstorms and earthquakes. The structures involved can include homes, hospitals, schools, churches, offices, industrial buildings, communication facilities, bridges, utilities and many others.

2. Broadly speaking, the failures result from deficiencies in design, poor quality in construction and lack of maintenance. These three problems go hand in hand and the prevention of disasters generally requires improvements in all these aspects. Of particular importance is the improvement of the quality of construction. This has not been adequately addressed and is likely to provide a key to reducing vulnerability. The presentation addresses this issue, as well as the need to improve design and ensure proper maintenance.

3. The lack of quality in construction is partly due to the fragmented nature of the industry - true in almost all countries - and the large number of interests involved in the process. These interests include the user or occupier, the owner, the investor, the insurer, the builders, the sub-trades, the materials suppliers, the design professionals, the building officials, the code writers and the inspectors. Each of these interests has a different

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attitude to the achievement of quality in construction; the lack of commitment on the part of some can frustrate the efforts of those that are committed. The ability to achieve quality is a limiting factor in improving the technical aspects of the design. The presentation examines, in the light of experience in very many countries, the potential contribution that each of these groups can make towards improving quality and disaster resistance, and suggests strategies for dealing with the matter.

4. Several vital preventive measures can be taken at the design stage to reduce vulnerability against windstorm and earthquake. They include, first and foremost, the assessment of risk of damage from knowledge of the seismicity and windstorm risk, as well as the magnitude and nature of the loading. The assessment of the extent of the impacted area is also discussed. Improved physical knowledge of the natural hazard phenomena plays a very important role. Techniques for lessening the vulnerability of structures are put forward.

5. The maintenance of structures is another aspect of disaster prevention. Techniques for assessing and upgrading existing strength is an important topic and has recently been studied more systematically.

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# NATURAL DISASTER REDUCTION: HAZARD RESISTANT STRUCTURES

## Technical session

## Addendum

### Summary of presentation made on behalf of the global engineering organizations WFEO/UATI by Mr. Stuart Mustow, President, Institution of Civil Engineers, and Dr. Scott Steedman, Member, Institution of Civil Engineers

1. Understanding of the effects of earthquakes or windstorm on structures has advanced considerably in recent years and has led to generally high standards of design codes and regulations in most countries, at least for certain classes of building. The evidence of continuing physical damage and loss of life in recent events, however, confirms the view that implementation of those codes is generally inadequate and that, as a result, many countries face an increasing risk from natural disaster as urbanization accelerates throughout the world. Two demonstration projects being carried out by the Institution of Civil Engineers for WFEO/UATI under the United Nations programme address these issues.

2. In the first project the vulnerability of megacities is being reviewed in collaboration with three cities each of which represents a major element in their national and regional economies: Jakarta, Karachi and Metro Manila. More details of this project are given in the technical session on the effects of disasters on modern societies.

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3. The second project is focused on the difficulties confronted in many countries in the implementation of building codes and regulations. Mitigation through improved construction practice is a goal which is frequently thwarted by the increased cost that the practice can impose. Limited resources for building inspection and control reduce the authority and effectiveness of those departments.

4. Education within the community and increased awareness of the risks can be developed in societies in which there is a recent history of local or national disasters. In countries which have not suffered from natural disasters in living memory, initiatives to mitigate the risk of future loss must, however, be carefully integrated with local political objectives which in general lie in other fields, such as water supply, transport or unemployment.

5. The presentation will illustrate these challenges using examples drawn from case-studies, including experience with the Erzincan (Turkey) earthquake of March 1992 and the Cairo (Egypt) earthquake of October 1992. Also, the important concept of seismic-hazard auditing will be illustrated by a case-study in Colombia.

6. Structural design and detailing is a key component in the mitigation of risk from natural hazard. Goals should be set for all countries for the promotion and adoption of good practice, not only in codes and regulations but also in education and training, building control and quality assurance.

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# NATURAL DISASTER REDUCTION: HAZARD RESISTANT STRUCTURES

## Technical session

## Addendum

## Protection of non-engineered housing from natural hazards

Summary of presentation by Dr. A.S. Arya, Professor Emeritus, Earthquake Engineering, University of Roorkee, India, and member of the Scientific and Technical Committee for the International Decade for Natural Disaster Reduction

1. It is well known that, year after year, millions of non-engineered houses (traditional vernacular dwellings of wood, clay, adobe, stone and brick laid in clay, mud etc.) are lost due to three natural disasters, that is, the floods, cyclones (typhoons and hurricanes) and earthquakes occurring around the world, particularly in the developing world. The consequent loss of human and cattle lives, damage to property and destruction of means of livelihood cause much misery to the survivors. Besides, such destruction becomes a tremendous drain on the economy of many countries and recurrence of disasters provides a big constraint against their development.

2. One of the cherished goals of the International Decade for Natural Disaster Reduction is, therefore, to develop the capacity of such disaster-prone countries to be able not only to cope with this challenge but also to reduce the disastrous effect by pro-active prevention and preparedness measures. There is at present considerable know-how available, partly

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developed indigenously in the countries, both through age-old experience of living with the disasters and partly through the research on disaster-resistant construction methods of such buildings carried out in the past few decades. These construction methods, which include proper choice or improvement of site, appropriate geometry of house plan and elevation, introduction of bands and braces in walls and roof, proper connection details for adequate integration of the various elements of the roof and the walls, waterproofing to minimize rain and flood damage, improvement in quality of construction and the like, are seen to be effective in reducing the damaging consequences of earthquakes, cyclones and floods on the common man's house. Being of an incremental nature (maintaining basic materials and construction techniques rather than replacing them wholesale), these are found to be socially acceptable, economically feasible and easily absorbed into local construction methodologies.

3. Considerable experience has also been gained throughout the world in reducing losses of life and property wherever the improved disaster-resistant methods were used in the traditional constructions. The presentation will highlight much improved methods and also the case studies of their successful application. The more important guidelines, manuals and codes available on this subject will be listed for ready reference.

4. Another issue to be addressed is the transfer of this technology to the local level (i.e., rural, semi-urban or even urban areas) where the problem of hazard damage of buildings exists acutely in most countries. It is known that in some countries considerable progress has been made in the agricultural and health sectors through extension services. An attempt is made to highlight such information and to make recommendations in regard to the dissemination and extension services which could propagate the use of disaster-resistant building technologies.

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# NATURAL DISASTER REDUCTION: HAZARD RESISTANT STRUCTURES

## Technical session

## Addendum

## Reconditioning of existing adobe housing to mitigate the effects of earthquakes

Summary of presentation by Professor Alberto A. Giesecke, Director, Centro Regional de Sismologia para America del Sur (CERESIS), Peru, and member of the Scientific and Technical Committee for the International Decade for Natural Disaster Reduction

1. Considerable work has been done throughout the world to produce new technology for adequate construction with adobe. Such efforts, however, do not mitigate the impact of future large earthquakes on existing adobe housing, since these technologies are not applicable, in general, for reconditioning older houses. It is therefore urgent and very important to address the problem faced by millions of people who live in adobe housing hoping they are lucky enough during their lifetime to be spared the occurrence of a destructive earthquake.

2. The problems with adobe construction when subjected to ground shaking are due to non-engineered construction, the inherent mechanical limitations of the material, massive yet fragile and low-resistant walls, and configuration defects that enhance the problem, such as long walls without transversal bracing elements, excessive height from floor to ceiling, inadequate wall to wall and wall to roof joints, and foundations in soft soils. After each important earthquake, a series of brochures and manuals are prepared and

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distributed, with an assortment of recommendations to improve the seismic resistance of adobe constructions, many of them with contradictory appreciations and, generally, without the benefit of laboratory or field tests to guarantee performance.

3. The basic concept of the CERESIS project is to evaluate and establish simple, low-cost procedures for reconditioning existing adobe housing, taking into account the type of soil on which they are built, and the size, shape and construction characteristics, so that they will resist seismic excitation at least to the extent that the occupants, when a severe earthquake occurs, will have enough time to get outside before the house collapses. The objective is to save lives. Tests of these procedures are being carried out on large-scale models using a large shaking table, which simulates earthquake-induced ground motion.

4. The project includes strategies to develop the proper methodology that would motivate the populations to carry out by themselves the recommended reconditioning without the help of outside experts or external financial aid.

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# NATURAL DISASTER REDUCTION: HAZARD RESISTANT STRUCTURES

## Technical session

## Addendum

## Development of light-weight natural rubber-based bearings for earthquake protection of small buildings

## Summary of the contribution by the Malaysia Rubber Producers Research Association

1. A project executed by the United Nations Industrial Development Organization and financed by the German Government was initiated in 1991 for a period of four years in order to develop and test a prototype base isolator for small-scale buildings. It is executed in cooperation with the International Rubber Development Board (IRDB), through which all rubber producing member countries participate. The coordination of the project, as well as most activities related to rubber technology, are entrusted to the Malaysian Rubber Research and Development Board which is cooperating closely with the Earthquake Engineering Research Center of University of California at Berkeley, United States of America. The Project has two basic objectives: (a) to devise a fully reliable but affordable device for earthquake protection of small and relatively low-cost buildings; and (b) to develop the technology for an advanced natural rubber-based product with an attractive market.

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2. To achieve this dual objective, the project has established a close cooperation among a number of institutions, each specialized in their field and responsible for essential components of the complex product development task. This involves, inter alia:

(a) Development of design methodology and design criteria for bearings for low load applications for which rubber-base isolation has not hitherto been applied;

(b) Preliminary design of bearings, including choice of reinforcement material, bonding adhesive and steel plate (especially end plate) dimensions;

(c) Systematic development of high damping natural rubber compounds and study of the effects of basic compounding ingredients on critical damping ratio, resistance to high amplitude fatigue, long-term durability and resistance to ageing;

(d) Comparative evaluation of various types of connection between bearing and structure including bolted, dowelled and recessed bearings;

(e) Trial mouldings of bearings and dynamic testing of prototype bearings under load to detect and correct deviations from rubber and overall design specifications;

(f) Design of experimental buildings to be constructed on prototype bearings and simulated and scaled down shaking-table tests of the completed base-isolated structure or parts thereof;

(g) Construction of demonstration buildings and performance evaluations of the rubber-base isolation system under real life conditions.

3. Two experimental buildings have been designed and are presently under construction, incorporating the base isolators developed by the project: the first at Pasir, Badak, Java, Indonesia (a four-floor concrete frame building with masonry infill); and the second at Shantou, Guangdon Province, China (an eight-floor concrete frame building with masonry infill). The prototype bearing developed for the two demonstration projects has the following specifications: 15 rubber layers, 14 reinforcing steel plates and two end plates, plate diameter 136 mm, total weight of rubber 1094 g, plate thickness 1.20 mm, endplate thickness 17.3 mm.

4. The presentation will describe the methodology of design and experimental work, including exemplary international cooperation, the performance characteristics of the prototype bearings, and the construction of the demonstration buildings of which the one in China will be described during a seminar held immediately prior to the Conference at Yokohama.

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